



Failure Simulation Testing of the Z-1 Spacesuit Titanium Bearing Assemblies

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Overview

- Introduction and Background
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- Test Plan Overview
- Test Hardware Description
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- Results and Discussion
- Conclusion



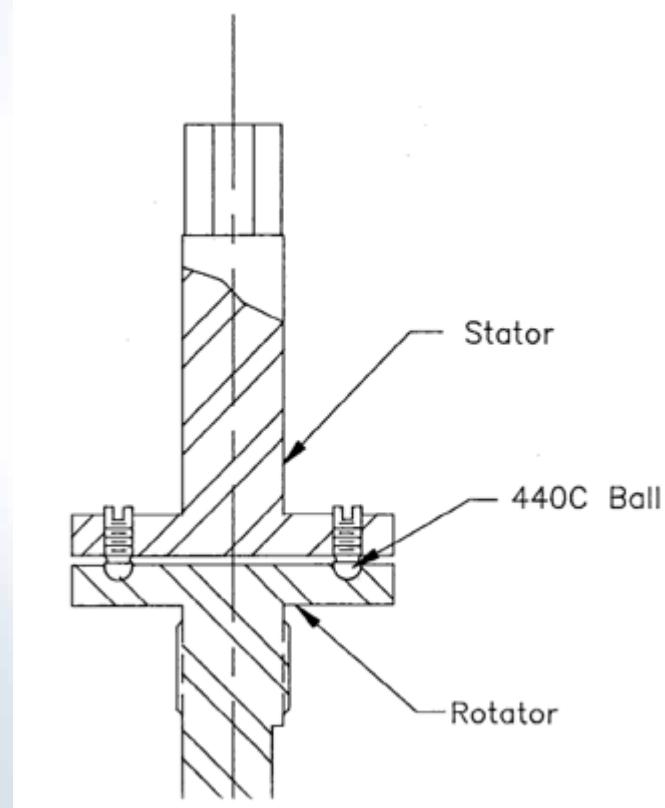
Introduction and Background

- Three Z-1 bearing assemblies were tested in support of Z-2 Suit development.
- Bearing constructed of titanium
 - Titanium is extremely easy to ignite
 - Will sustain burning in sub-ambient pressures
- Early 90's Test of ZPS Mk III
 - Ignitions were obtained
 - No bulk material burning



Introduction and Background

Early 90's Test Configuration



Test Results





Test Objective

- Evaluate whether a damaged or failing bearing could result in ignition of the titanium race material due to friction.
 - Simulated worst-case environment, with operational loads, and anticipated flaw conditions
 - Loads were comprised of plug and manned loads
 - Values for these loads used in the testing were derived from previous testing done on the current Extravehicular Mobility Unit (EMU)



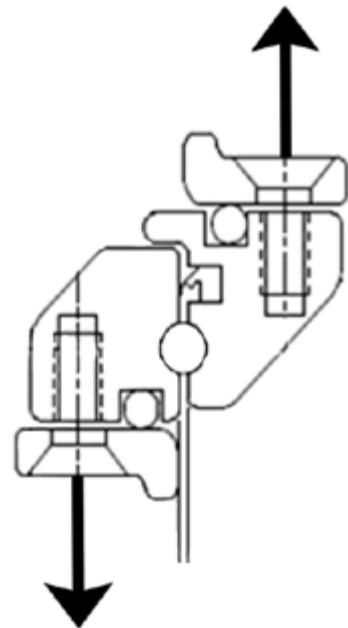
Test Plan Overview

- Testing simulated two simultaneous undetected failures
 - Inner seal leak sufficient to pressurize the race with +99 percent oxygen.
 - Improperly installed or mismatched ball port that created a protrusion in the ball bearing race, partially obstructing the nominal rolling path of each ball bearing.
 - Simulated mismatched ball port is a significant source of friction that would be caused by an assembly error.
- Two Phases of testing
 - 96 hours of cycle time
 - Cycle rate, speed, and simulated loads based on previous manned suit testing
 - Increased load on each bearing for 30 minutes
 - Tests done at 12.4 psia

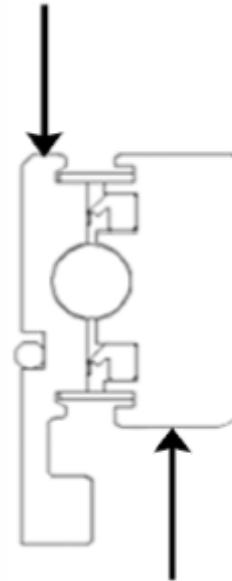
Test Hardware Description

- Three bearing assemblies representing the hip bearing, scye (shoulder) bearing, waist.

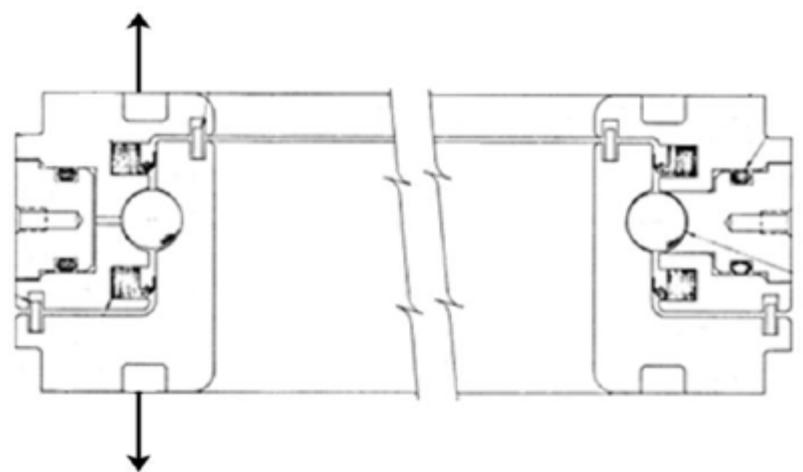
Hip Cross section



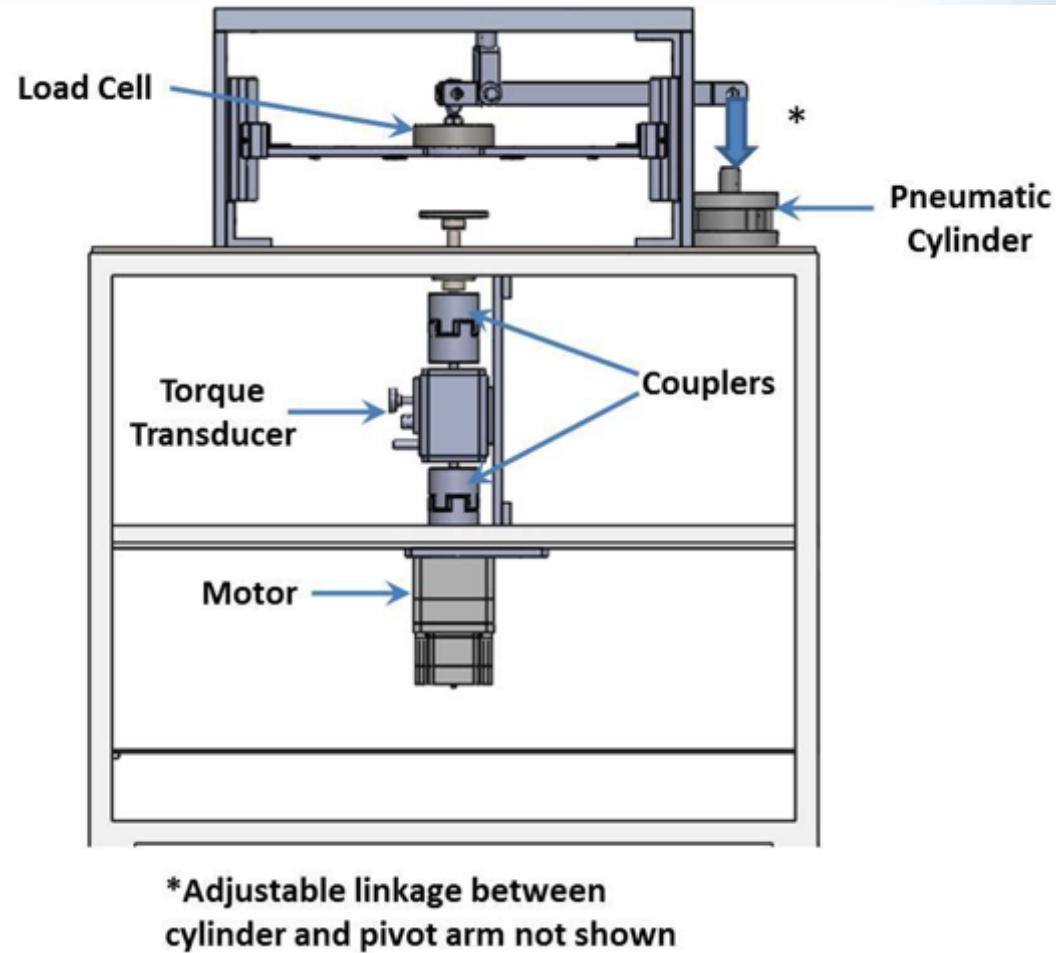
Scye Cross section



Waist Cross section



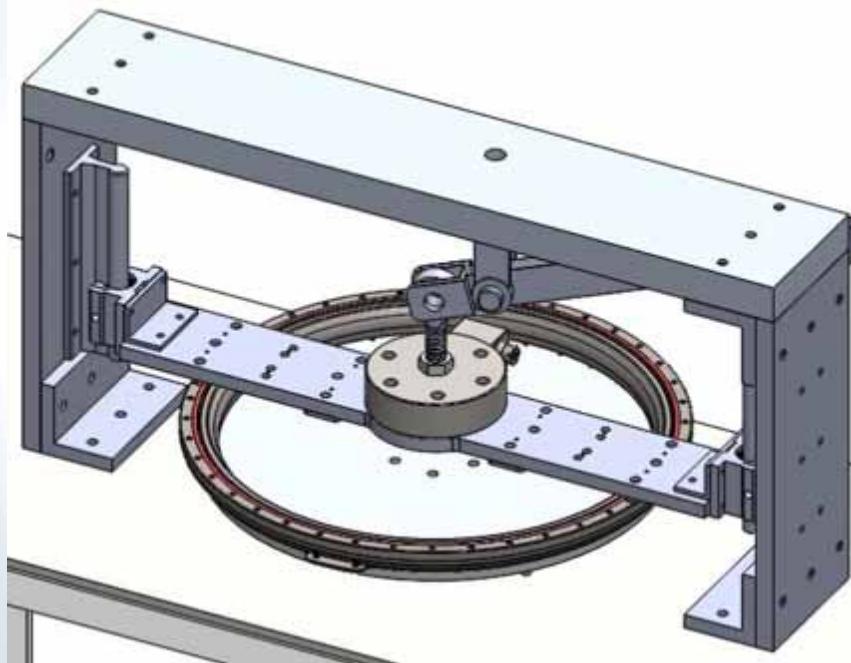
Test Hardware Description





Test Hardware Description

Hip Bearing Test Configuration

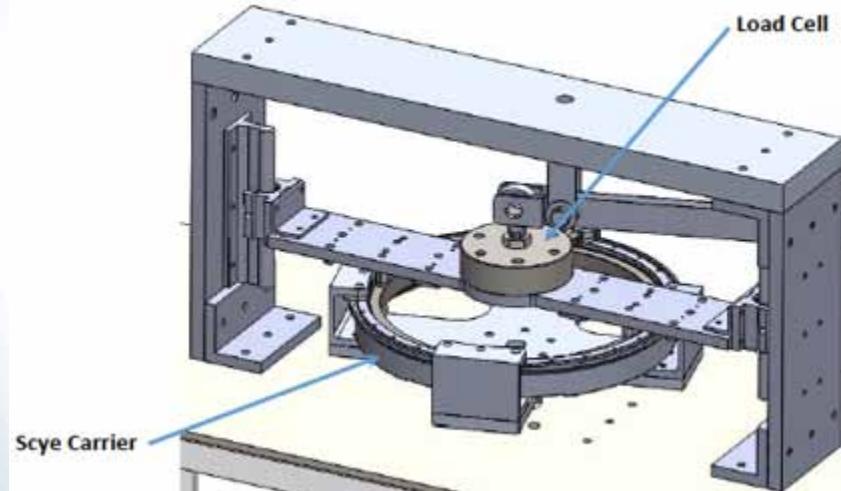




Test Hardware Description

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Scye Bearing Test Configuration

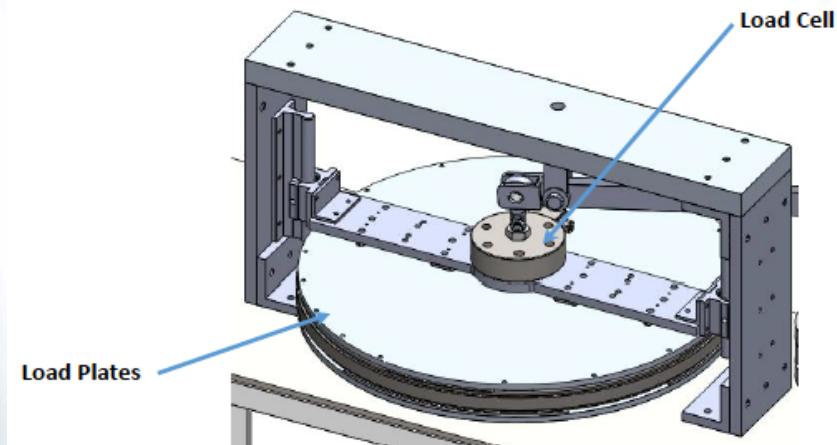




Test Hardware Description

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Waist Bearing Test Configuration





Test Parameters

Table 1. Test Profiles

| Test Article | Max Velocity (deg/s) | Max Arc (deg) | Cycles | Bearing Diameter | | Pressure (psia) (kPa) | Media O ₂ | Load ^a (lb) (kg) |
|--------------|-------------------------|------------------|---|------------------|--------|-----------------------------|-------------------------|-----------------------------------|
| | | | | (in.) | (mm) | | | |
| Hip | 78 | 45 | <i>96 h of</i> 20/min - 1 h 40/min - 45 min <i>Phase II:</i> <i>30 min @</i> <i>52/min</i> | 11.74 | 298.19 | 12.4 | 85.5 | +99% 1111 504 |
| | | | <i>52/min - 30 min</i> | | | | | |
| Scye | 135 | 135 | <i>96 h @ 20/h</i> <i>Phase II:</i> <i>30 min @ 20/h</i> | 9.21 | 233.93 | 12.4 | 85.5 | +99% 720 326.6 |
| | | | | | | | | 850.2 385.6 |
| Waist | 52 | 30 | <i>96 h of</i> 20/min - 1 h 40/min - 45 min <i>Phase II:</i> <i>30 min @</i> <i>52/min</i> | 15.53 | 394.46 | 12.4 | 85.5 | +99% 1983 899.4 |
| | | | <i>52/min - 30 min</i> | | | | | |

^a Sum of plug loads @ 8.8 psia (60.7 kPa) and manned loads.

Results and Discussion

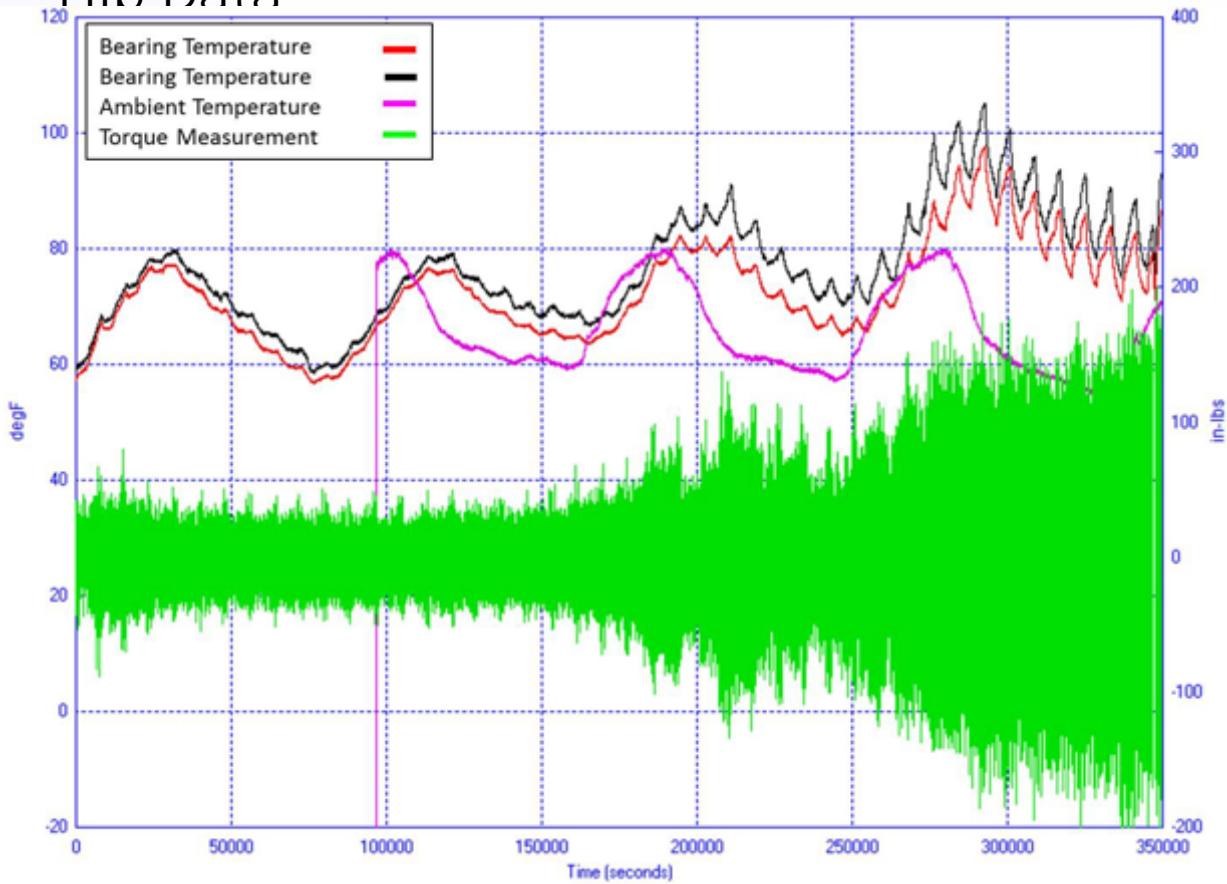
- Hip Bearing "Failure"





Results and Discussion

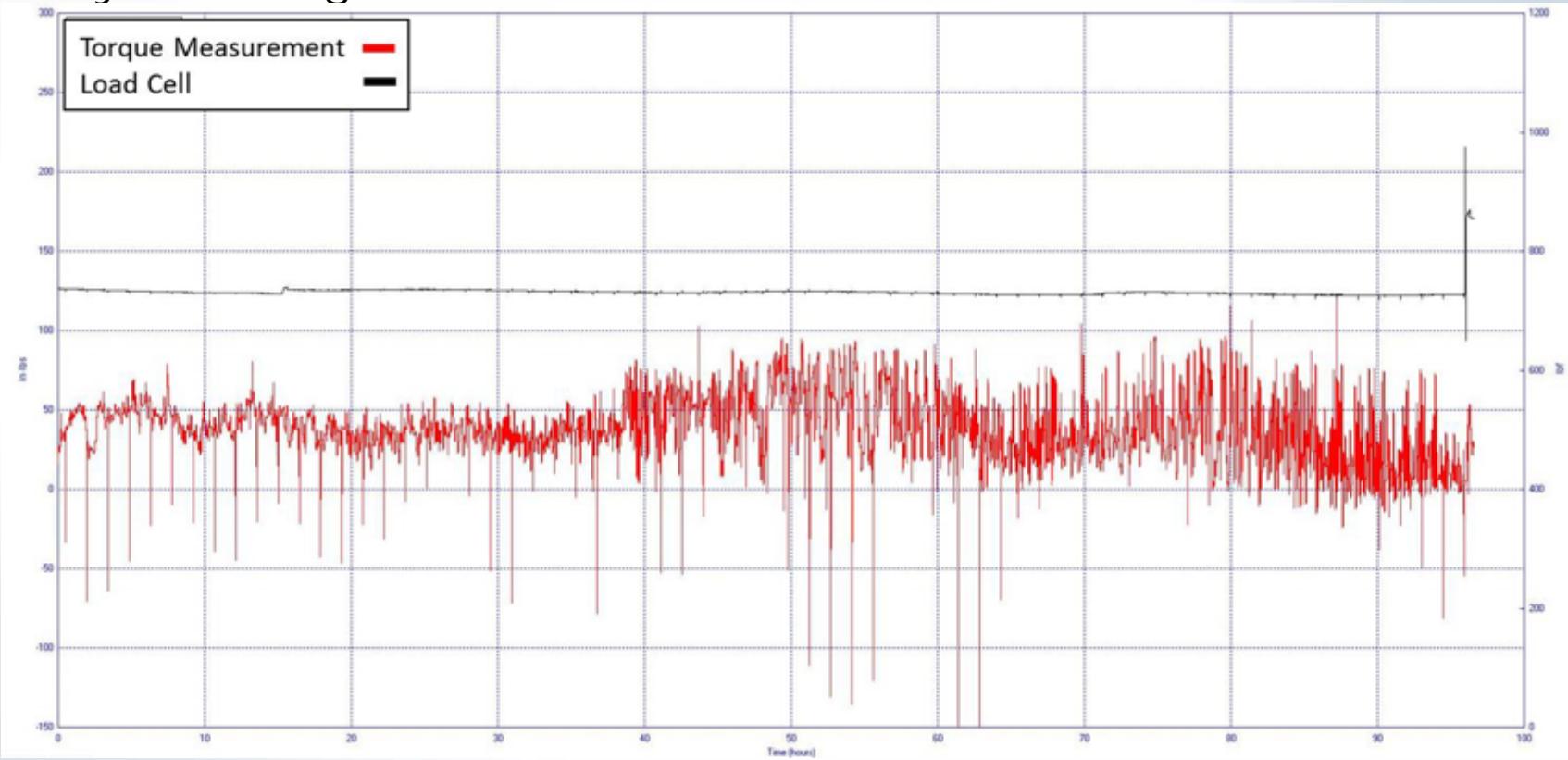
■ Hip Data





Results and Discussion

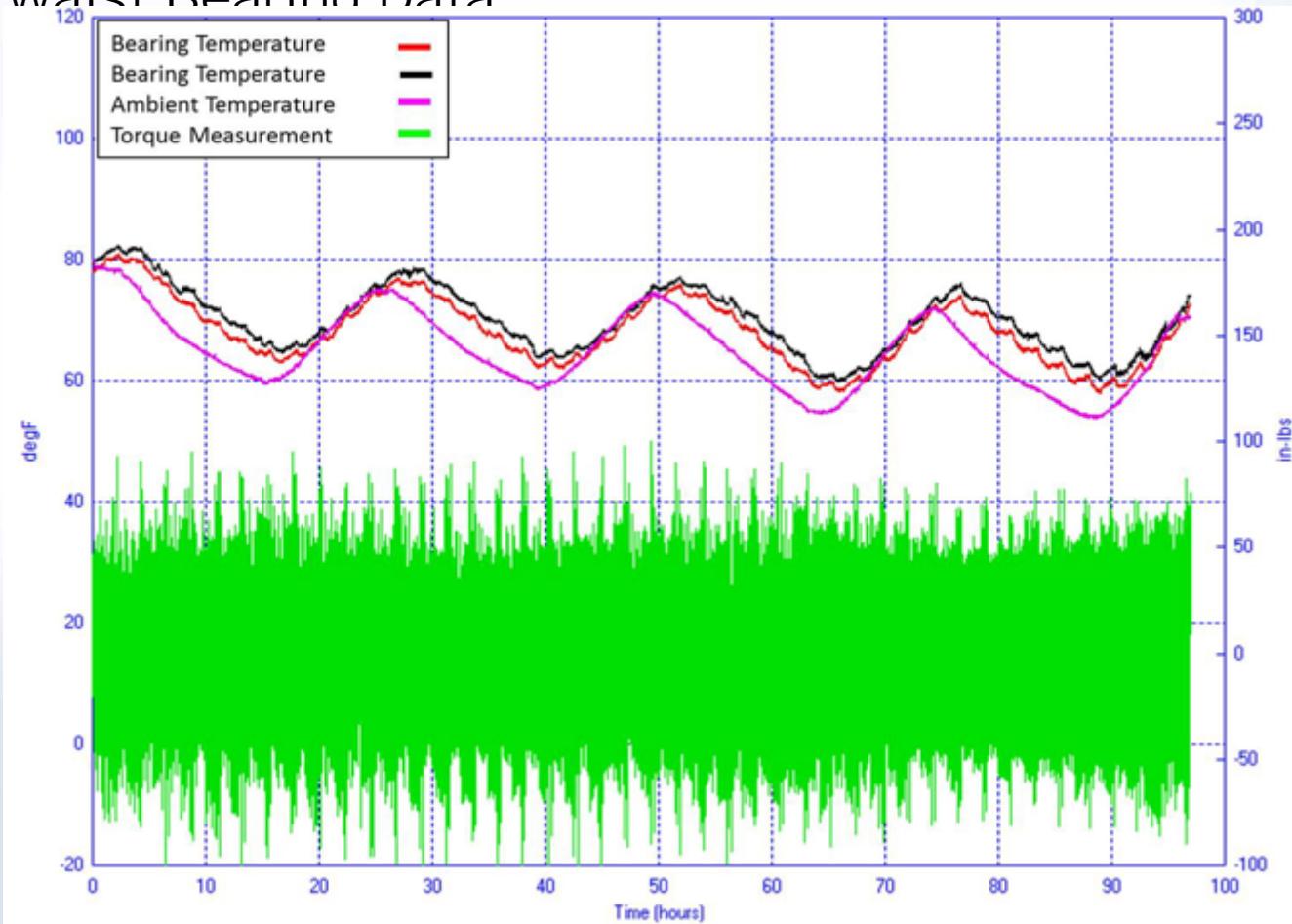
■ Scye Bearing Data





Results and Discussion

■ Waist Bearing Data





Results and Discussion

- Follow on Testing
 - Additional testing performed on a hip bearing assembly to further investigate the mechanical wear of the bearing witnessed and the effect of maintenance on the performance of the bearing.
 - After the massive amounts of wear and debris seen in the hip, it was suspected that the bearing lubricant was drying out and the buildup of worn ball bearing debris was then becoming a contributing factor to the overall bearing wear.
 - It is now believed that the ball bearing wear was more of a contact stress problem.



Conclusion

- Testing in 1990s showed titanium in the tested configuration was difficult to ignite - in extreme test conditions.
- A different bearing design and the understanding of how to safely use previously unacceptable materials (like titanium) has matured from 20 years ago.
 - This series more refined and more in line with the way the bearings would be used and or might fail.
- None of the bearings tested exhibited signs of ignition upon posttest bearing disassembly and inspection.
- The test results demonstrated that the use of titanium in this specific application is worth pursuing in further maturing the bearing and suit design.



THANK YOU